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MODULATION-DELAY EQUALISATION APPLIED TO COMMON-FREQUENCY H.F. CIRCUITS:
an assessment of the likely improvement

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Summary

This Report describes tests that were carried out to assess the maximum improvement that modulation-delay equalisation, of the type that had been found beneficial for m.f. broadcasting,[1] *could provide for reception of common-frequency h.f. broadcasting.*

The tests involved tape and pen-chart recordings of special common-frequency h.f. transmissions from Daventry, Rampisham, and Woofferton that were received by the kind co-operation of RAI at their receiving station at Monza, near Milan.

From an assessment of both types of recordings it was concluded that the improvement would be too small to justify the provision of modulation-delay equipment at h.f. stations.

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1. Introduction

In order to cover very large and irregularly-shaped areas in various parts of the world, most BBC External Services programmes are broadcast simultaneously from several transmitters, the outputs from which are beamed in various directions. The shortage of carrier frequencies that are favourable at any given time often makes it desirable for some of the transmitters that broadcast the same programme (the BBC World Service, for example) to share a common carrier-frequency. In the so-called 'mush areas', where the service areas of these common-frequency transmitters overlap, however, it has been reported that reception is sometimes impaired by their mutual interference.

For the case of day-time reception at m.f. it has been shown that this type of impairment can be substantially reduced by equating the times of arrival of the two modulations in the overlap areas[1] and it was suggested that the same technique might provide a worthwhile improvement at h.f. It was recognised, of course, that the improvement gained during the day-time at m.f. was due largely to the stability of the ground-wave propagation path and that the variable nature of the sky-wave path at h.f. would most probably reduce the improvement that the technique could provide for reception in the h.f. band. It was therefore decided to conduct the tests over what was considered to be one of the most stable h.f. paths in order to assess the maximum improvement that modulation-delay equalisation could provide under the most favourable conditions and to assess whether or not even that would be worthwhile.

2. Description of tests

2.1. Basis of test

The maximum improvement that would be gained if perfect modulation-delay equalisation were provided for a pair of common-frequency transmitters could readily be assessed by feeding both transmitters with the programme signal in the normal way (i.e. without modulation-delay equalisation) and then, whilst receiving the resultant of the two in a mush area involving the most stable propagation path from both transmitters, to switch off each of the two transmitters in turn. Transmitters were chosen that were located in different parts of the UK so that their modulations would be subject to typically different delays. The carrier drive equipment at each transmitter was accurate to 2 parts in 10^{10} but no provision was made to synchronise each pair of carriers. Thus a beat frequency of up to 1 cycle in 2.5 minutes could occur between two 15 MHz carriers. As will be shown in Section 3, the presence of this carrier beat proved helpful during the tests.

The most stable propagation path was considered to be a single-hop path involving E-layer reflection, such as is used for broadcasting to the nearer parts of Europe. Accordingly, special transmissions using this mode were arranged from pairs of common-frequency transmitters in the UK to a receiving site at Monza, in N. Italy. The power radiated from one transmitter of each pair was trimmed so as to equate the two median field-strengths at the receiving site, thus producing the maximum possible mutual interference there. A staggered sequence of transmissions was adopted by which one transmitter of each pair was powered for 30 minutes, after 15 minutes of which the second transmitter of the pair was powered for 30 minutes. In this way, the quality of reception could be assessed over three consecutive 15-minute periods covering the conditions both for either transmitter alone and for both transmitters together. Periods of this duration were found to be necessary in order to average the varying propagation conditions when assessing the comparatively minor changes caused by powering either or both transmitters. Pen-chart recordings of the resultant field-strength (for every broadcast test sequence) and tape recordings of the received programme (for roughly half of the broadcast test sequences) were made at the receiving site at Monza and were returned to the UK for study.

2.2. Transmission details

Details of the special transmissions, radiated from transmitters at Daventry, Rampisham and Woofferton, are given in Table 1.

The transmissions were radiated on 12th, 14th and 16th May 1975 and again on 19th, 20th, 21st, 22nd, 26th, 27th, 28th and 29th August

TABLE 1

Transmission Details

Time (GMT)	Frequency (MHz)	Transmitter(s)	Aerial array	Bearing of max. (ETN)	Firing angle of max.
0900 to 0915	15.39	Daventry only (Sender 20)	$\mathrm{HR}/2/2/^{0.6}_{0.7}$ (Array 26)	140°	12°
0915 to 0930	15.39	Daventry and Woofferton			
0930 to 0945	15.39	Woofferton only (Sender 96)	HRR/2/4/1 (Array 928A)	114°	7°
1015 to 1030	11.68 or 12.04	Daventry only (Sender 20)	$\mathrm{HR}/2/2/^{0.6}_{0.7}$ (Array 25)	140°	12°
1030 to 1045	11.68 or 12.04	Daventry and Rampisham			
1045 to 1100	11.68 or 12.04	Rampisham only (Sender 40)	$\mathrm{HRR}/2/2/^{0.6}_{0.7}$ (Array 320A)	114°	12°

1975. Those from 1015 to 1100 hrs (see Table 1) were radiated at 11.68 MHz on all the days except 19th, 28th and 29th August when they were radiated at 12.04 MHz.

As described in Section 2.1, the transmissions were received at Monza after travelling via one-hop paths. In order to equate the median field-strengths, there, for each pair of transmitters, and thus maximise the mutual interference between each pair, it was arranged to use transmitter powers of 150 kW at Woofferton and 250 kW at Daventry and Rampisham.

For all the transmissions, the carriers were modulated by the BBC World Service programme, using double-sideband amplitude-modulation in accordance with standard BBC practice for h.f. broadcasting. The normal programme circuits to the transmitting stations were used; no special attention was paid to their phase or delay characteristics as a function of modulation frequency.

2.3. Propagation details

As stated in Section 2.1, the transmission times and carrier frequencies were chosen so as to favour E-layer reflections. Experience has shown these to be more stable than F-layer reflections and they are thus used for h.f. broadcasting on 11 MHz and 15 MHz from the UK to Western Europe in daylight during the Summer months. Transmissions at these frequencies were therefore chosen for the tests, not only because they would represent normal broadcasting conditions but also because, due to the greater stability of the propagation path, mutual interference effects between the pairs of transmitters would be more evident. For those same reasons a receiving site was chosen that was served by a one-hop path.

Details of the propagation paths used for the tests are given in Table 2. It is likely that the differences between the propagation times given in this Table are relatively small compared with those between the programme circuits feeding the transmitters (approx. 1 ms).

2.4. Reception details

The special transmissions described in Table 1 were arranged to be received with the kind co-

TABLE 2

Details of Propagation Paths

Site			Path to Monza		
Station	Latitude	Longitude	Great circle distance (km)	Path* length (km)	Propagation time* (ms)
Daventry	52°15′N	01°08′W	1,058	1,092	3.64
Woofferton	52°19′N	02°43′W	1,140	1,172	3.91
Rampisham	50°48′N	02°38′W	1,052	1,086	3.62
Monza	45°35′N	09°16′E	—	—	—

* Assuming E-layer reflection at 115 km.

operation of RAI at their receiving station at Monza, about 13 km NNE of Milan. The transmissions were received using a normal d.s.b. receiver having an envelope detector (Rhode and Schwarz type EK-070).

A pen-chart recording showing the amplitude of the resultant signal as a function of time was made during each transmission. Audio tape recordings were also made of the programme signals received during the six transmissions radiated in May 1975 and during four of the transmissions radiated in August 1975. The pen-chart and tape recordings were returned to the UK for study.

Results based on these recordings are discussed in the next Section.

3. Results

Both the tape recordings and the pen-chart recordings showed that propagation conditions from the UK to Monza varied considerably from one test transmission to another. The depth of fading was about 25 dB for virtually every transmission, but the fading period varied from a few seconds to a few minutes from one transmission to another. Distortion caused by selective fading was nearly always present but it was seldom sufficiently severe to render the programme unintelligible. Distortion due to this cause, although very similar to that due to mutual interference between pairs of transmitters could be distinguished from it by the latter's cyclic character.

The ratios of the median field-strengths received at Monza during the first and last fifteen-minute periods of each test transmission (i.e. received from each single transmitter in turn) were deduced from the pen-chart recordings and are shown in Table 3. (No result can be quoted for the second transmission on 14th May 1975 because its first fifteen-minute period was missed. Furthermore, no explanation can be given for the very low field-strengths observed throughout the first fifteen-minute periods of the first test transmissions on 22nd and 26th August 1975.) It is clear, however, that the median field-strengths at Monza from each transmitter of each pair during the remaining nineteen test transmissions were all as nearly equal as could be expected. Nevertheless, mutual interference between transmitters was seldom noticeable on the tape recordings made during the test transmissions; i.e. the quality of the received signal was very seldom worse when two transmitters were both powered together than when either was powered on its own. The reason for this is discussed below.

It has been shown that, without modulation-delay equalisation but under perfectly stable propagation conditions, mutual interference between pairs of common-frequency common-programme transmitters becomes perceptible if the ratio of their field strengths is 9 dB or less.[1] The severity of the interference varies cyclically at the carrier-beat frequency as the phase-difference between the two carriers varies, and is worst when they are in anti-phase. If the field-strength ratio is 9 dB, the interference if perceptible for only the brief periods whilst the two carriers are approximately in the anti-phase condition. As the two field strengths approach equality, however, the

TABLE 3

Median Field-strengths Observed at Monza

Date	Ratio of median field-strengths (dB) during first and last fifteen-minute periods		Date	Ratio of median field-strengths (dB) during first and last fifteen-minute periods	
	0900 to 0945 transmission	1015 to 1100 transmission		0900 to 0945 transmission	1015 to 1100 transmission
12.5.75	+11.0	+2.0	22.8.75	−30.8	−3.7
14.5.75	+3.7	no result	26.8.75	−23.6	−4.5
16.5.75	−1.7	+1.5	27.8.75	+4.6	+4.1
19.8.75	−7.1	+6.8	28.8.75	+1.3	+1.5
20.8.75	+1.8	−3.2	29.8.75	+1.3	+0.7
21.8.75	+0.6	+3.7			

interference becomes more severe in the anti-phase condition and is perceptible during a larger proportion of the carrier-beat cycle.

Distortion caused by selective fading on the propagation path masks this type of interference and, under the conditions that applied during the test transmissions, it was found that the mutual interference was not perceptible, even in the anti-phase condition, unless the ratio of the two field-strengths was less than about 6 dB. This result was established by inspecting pen-chart records of the resultant field strength that were made at times when the interference was audible on the tape recordings. Conditions which caused audible mutual interference also caused a characteristic cyclic pattern on the pen-chart records, at the beat frequency between the two carriers (see Section 2.1), from which the field-strength ratio could be deduced. The presence of this carrier beat was helpful during the tests because, due to the regularly recurring distortion that it caused at the beat frequency, the effect of the mutual interference between the two carriers could readily be distinguished from that of selective fading.

Thus, for the interference to be audible, the two carriers needed to be approximately in anti-phase at times during the fading cycles when the ratio of their two field-strengths was less than 6 dB. Since the propagation conditions were so variable, these two conditions seldom applied simultaneously and so the interference was seldom audible. The improvement to reception that modulation-delay equalisation would provide is therefore considered to be too small to justify the provision of modulation-delay equipment in the programme signal feed to h.f. stations.

4. Conclusions

This Report has described tests that were conducted to assess the maximum improvement that modulation-delay equalisation could provide for h.f. reception.

It has been shown that, due to the varying propagation conditions at h.f., the improvement to reception, even over the most stable single-hop circuits, would be too small to justify the provision of modulation-delay equipment at h.f. stations.

5. Acknowledgement

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6. Reference

1. WHYTHE, D.J. Reduction of mush-area

distortion in common-frequency m.f. transmitter networks. BBC Research Department Report No. 1976/5, February 1976.

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